Aquaculture Feeding and Growth Experiments Comparing Bluegill and F_1 Hybrid Sunfish (male bluegill x female green sunfish)

An Honors Thesis (HONORS 499)

by

Kenton J. Hanauer and Mary M. Picconatto

Ball State University

Muncie, Indiana

April 1992

Expected Date of Graduation May 1992

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THESIS ABSTRACT

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Possible differences in food consumption, growth, and food conversion comparing groups of six bluegill (Lepomis macrochirus) to six hybrid sunfish (male bluegill x female green sunfish (Lepomis cyanellus)) were evaluated over a 64 day total period from December 12, 1991 to February 14, 1992. Each fish was held in an individual aquarium with a daily 12 hour photoperiod of natural light supplemented with overhead fluorescent lighting. Daily maximum and minimum water temperatures ranged from 58 to 69^{o}F. Fish were fed an ad libitum ration of frozen brine shrimp (Artemia sp.) twice daily between 0700-1000 hours and 1600 -1900 hours. The 64 day total period was divided into sequential 22, 20, and 22 day periods with fish weighed and measured at the beginning and

at the beginning and end of each period. Examination of data revealed a significant difference (t-test; $P<0.05$) in the amount of food consumed for all periods with bluegill consuming more food than hybrid sunfish. There were no significant differences observed between bluegill and hybrid sunfish in conversion efficiencies for any of the three experimental periods (t-test; $P>0.05$). Evaluation of weight gain and length gain per day revealed no significant differences (t-test; $P>0.05$) except in period 1 with bluegill growing more than hybrid sunfish. These results must be interpreted with care since fish were isolated and social mechanisms excluded. Social interactions appeared to have some importance in the feeding behaviors of the fish, particularly the hybrid sunfish. A follow up test using all twelve of the original experimental fish together in the main raceway tank provided insight into this phenomenon.

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INTRODUCTION

The aquaculture industry has been a growing part of the agriculture industry in the United States since the early 1980's. In light of this expansion, aquaculture experiments were initiated in September of 1991 at Ball State University. Sunfish present an appealing option for aquaculture in Indiana and the region, because they exhibit growth characteristics compatible with regional conditions while being perceived as a desirable food and sport fish by the public.

Experiments with bluegill (Lepomis macrochirus) and F_1 hybrid sunfish (male bluegill x female green sunfish (Lepomis cyanellus)), were initiated to evaluate potential differences between the two species with regard to the suitability of the fish for aquaculture. The bluegill was chosen because of it's popularity as a sport fish. The hybrid was selected because of it's potential hybrid vigor and supposed better growth associated with aggressive feeding. Differences in food consumption, growth (weight and length), and food conversion were evaluated in the comparison.

ACKNOWLEDGEMENTS

We would like to thank Allan Winters and Janet Tuhey, for their help in maintaining the greenhouse tank, feeding the experimental fish during periods when we couldn't be present, and allowing us to share their space in the greenhouse.

Thanks are also in order for Scott Tollentino and Kevin Mc Keag. Without their help and patience we would still be writing.

Special recognition is given to the Honors College and the Biology Department for their support and encouragement. It is not often that undergraduates are given the opportunity to conduct this type of research.

Finally, a special thank you to Dr. Thomas S. Mc Comish, for keeping us on top of things and pushing us to achieve. His guidance and support have been more important than he will ever know.

LITERATURE REVIEW

Aquaculture is a rapidly growing industry. An indication of its expansion is the increased number of journal publications dealing with aquaculture. These include Water Farming Journal, Catfish Aquaculture News, The Aquaculture News, and North Central Regional Aquaculture Center (NCRAC) Journal. Expansion has occurred as a result of an increased demand for fisheries products, a leveling off of commercial landings, and the ability of the industry to produce high quality products at competitive prices (Broussard 1991).

Sunfish are considered desirable as food and sport fishes by the public (Kaufman 1973). Additionally, they exhibit growth characteristics compatible with conditions in our region. For these reasons, the sunfish present an appealing option for aquaculture in this state and region.

Two sunfish species present in Indiana are the bluegill and the green sunfish. Bluegill have historically been an important fish in pond management (Carlander 1977). Additionally, the species has value in being highly adaptable to diverse conditions (Kaufman 1973). An example of this adaptability is the ability of the species to alter niches as a response to competition. Bluegill forage primarily in the littoral zone, their preferred habitat (Werner and Hall 1979). However, in the presence of competitive species, they have the ability to migrate to the open water and utilize zooplankton as their food source (Werner and Hall 1976). Furthermore, they are highly regarded as a sport and forage fish.

Green sunfish are efficient at foraging and use resources more effectively than bluegill (Werner and Hall 1979). Under identical densities in preferred habitat, green sunfish exhibit significantly greater growth and therefore, presumably greater fitness (Werner and Hall 1977). Additionally, they are more aggressive. Green sunfish clearly dominate bluegill of the same size in aquaria to the point that cohabitation is not possible (Greenberg 1947). However, as a food and sport fish the green sunfish is not considered as desirable as the bluegill. Under natural conditions, the green sunfish rarely reaches a size considered to be of interest for a food or sport fish (Carlander 1977).

What seems the ideal, then, would be a combination of bluegill size and adaptability characteristics with green sunfish aggressiveness and foraging characteristics. The hybridization of bluegill and green sunfish might accomplish this ideal. According to Hubbs (1955), hybrids are intermediate in taxonomic characters between parental species. This intermediate condition displays characteristics that cannot be attributed to either parent and is thought to be a result of hybrid vigor or heterosis.

Heterosis accounts for several characteristics of hybrids. Among these are an increased growth rate, higher adaptive plasticity, and a more rapid sexual maturation (Bennett 1971). These attributes make the hybrid favorable for the demands of fish management. Hybrids may also fill available niches that other fish cannot utilize. It has been noted that native game fish utilize only 25% of the water volume in aquatic systems, where hybrids increase water usage, foraging in less used areas of a pond, lake, or stream (Dalrymple 1986). Another characteristic of hybrids is the acceptance of supplemental food such as pelleted prepared food (Lewis and Heidinger 1971), making them acceptable for use both in aquaculture and as experimental fish.

One such hybrid is the result of a cross between male bluegill and female green sunfish. This cross exhibits rapid growth (Childers 1967), as well as probable hybrid vigor including increased aggression. In fact, the bluegill x green sunfish hybrids exceeded the average growth for bluegill in Illinois ponds (Brunson and Robinette 1986). Additionally, the cross produces mostly male offspring (Brunson and Robinette 1986). This increased growth and aggression may be desirable for aquaculture as well as use in farm ponds, urban-metro lakes, and youth fishing programs (Dalrymple 1986).

MATERIALS AND METHODS

Tank Description

Aquaculture experiments were conducted in a raceway tank located in the northeast section of the Ball State Greenhouse. The concrete tank measured 118 cm x 338 cm and 116 cm deep (46 in x 133 in and 45 in deep). The tank was lined with clear plastic to seal it and to provide a smooth, cleanable surface safe for fish and other aquatic organisms. A flow-through system was utilized in which tap water entered through a dechlorination chamber at the west end of the tank, flowed into the main raceway, and exited through a drainage standpipe at the east end.

Dechlorination of water occurred in a partitioned chamber 118 cm x 89 cm and 116 cm deep (46 in x 35 in and 45 in deep) at the west end of the system. A plastic netting and sheet were held as a screen by a wooden frame painted with gray enamel, forming the barrier between the main tank and the dechlorination chamber. Water flow between these areas was restricted to the narrow (up to 10 mm; 3/8 in) spaces at the junction of the partition and the tank walls. Dechlorination was achieved using a series of two, 121 L plastic containers. Tap water entered the first container from the faucet, and partial dechlorination was achieved there through vigorous aeration. The partially dechlorinated water then flowed through two pipe connectors (10 mm; 3/8 in diameter) from the first container into the second where aeration continued. Water exited the second container through a single drain pipe (10 mm; 3/8 in diameter), dropping 21.0 cm (8.3 in) to the water level in the partitioned chamber. Further aeration continued with multiple airstones at various locations within the chamber. Finally, dechlorinated water entered the main tank through the spaces (up to 10 mm; 3/8 in) at the junction of the partition and the tank walls. Supplemental aeration in the main tank was provided by four airstones, one in each corner. On the average, 26-27 L per hour flowed from the second plastic container into the partitioned chamber and through the main tank. This flow provided a theoretical turnover of water in the tank every five days.

A floating frame (71 cm wide x 140.5 cm long; 28 in wide x 55.3 in long) constructed of wood, and painted with gray enamel, held twelve individual wastebasket aquaria in two rows of six. The frame with aquaria was positioned in the main raceway tank using ties so that it was free floating, yet remained close enough to the edge to allow observations while feeding. Dimensions of the main raceway (west end) were 118 cm x 249 cm and 116 cm deep (46 in x 98 in, and 45 in deep). Each individual aquarium was 19.5 cm x 24.9 cm and 30.7 cm deep (7.7 in x 9.8 in, and 12.1

in), holding approximately 17.5 L of water. Water was allowed to flow freely through individual aquaria through multiple (52) 6 mm (1/4 in) holes in all four sides of the basket, starting approximately 50 mm (2 in) above the bottom of the aquarium and ending just below the surface of the water. Aeration and circulation of water were promoted by a single airstone positioned near the bottom of each aquarium.

Conditions

The experimental period was 64 days long, beginning December 12, 1991 and ending February 14, 1992. It was broken into three sequential 22, 20, and 22 day periods designated period 1, period 2, and period 3. Additional experimentation in the main raceway tank took place between February 28 and March 19, 1992.

Analysis of water quality was used to monitor environmental conditions of the system. Analyses of pH, dissolved oxygen, alkalinity, chlorine, nitrate, and nitrite concentrations were completed four times during the experimental period, approximating the beginning or end of each sample period. Additional testing of chlorine was completed on a continuous basis approximately every five days. Samples were collected from four separate sites for all tests. These were at the tap (source of the water at faucet) flowing into the first plastic container of the dechlorinator, at the exit pipe of the second plastic container into the dechlorination chamber, at the standpipe at the east end of the main raceway tank, and from aquarium number nine as a representative aquarium sample. Maintenance of water quality was facilitated by the flow-through nature of the tank. The complete theoretical turnover of water helped to reduce the build-up of waste materials (i.e. nitrates, nitrites). Additionally, supplemental aeration in the main tank was used to facilitate the breakdown of waste materials and to maintain dissolved oxygen near saturation levels.

A twelve hour photoperiod was maintained by natural light supplemented with four, adjacent, overhead, cool, white, fluorescent lights of 40 watts each. The supplemental lights were regulated by a Paragon Electric Timer, model 4005-00S, set to turn on lights at 0700 h and to turn off lights at 1900 h.

Fifteen hybrid sunfish were introduced to the raceway tank on September 20, 1991. Bluegill introduction occurred on October 25, however only three survived. A subsequent attempt at introduction of bluegill occurred on October 30. Fish in this assemblage were acclimated to the tank water between 1145 h and 1615 h and then released into the system. On November 1, 1991, both hybrid sunfish and bluegill were seined from the raceway tank and placed into individual wastebasket aquaria.

Twelve experimental fish were held in isolation, with one in each wastebasket aquarium, for a total of six hybrid sunfish (fish 1-6), and six bluegill (fish 7-12). Isolation allowed known amounts of food to be fed to each fish while inhibiting the transfer of excess food between aquaria. Additionally, isolation eliminated social interaction and competition as a variable to feeding. The fish were fed weighed portions of frozen brine shrimp (Artemia sp.) in near ad libitum amounts twice daily between 0700 - 1000 h and 1600 - 1900 h. Prior to feeding, frozen portions were weighed to the nearest 0.01 g on a Mettler top pan balance, recorded, and placed in plastic food containers for storage. All weighed portions were stored as frozen cubes in a standard freezer. Near ad libitum feeding was accomplished through the introduction of small portions of shrimp (about 5 mm x 5 mm) cut from each frozen cube with a knife and fed to each fish. When the total amount in the weighed portion for an individual was consumed, another weighed portion was assigned to the same fish and then fed. The feeding process was continued in each daily period until each fish no longer accepted the small cut portion of shrimp or spit it out.

Excess food was returned to the freezer. At the end of each period, uneaten portions were weighed, subtracted from the total weighed food or sum of all portions for each fish, with the total representing the estimated amount of food consumed by each individual fish. It should be noted that some food was uneaten but it was minimal. No attempt was made to quantify uneaten food, thus food consumed was always an overestimate.

Data Collection

Water quality analyses were completed four times during the experimental period; December 18, January 3, January 27, and February 13. Water taken from each of the four experimental sites was placed in 3.8 L jars and transported to the laboratory for analysis.

The pH was determined using a Beckman model 21 portable digital pH meter. The meter was standardized using a pH 8.3 standard solution.

Dissolved oxygen was determined according to a slightly modified Standard Winkler Method (Standard methods 1971). Four 300 mL BOD bottles were filled; one at each sample site. First, 2 mL of manganous sulfate solution and 2 mL of alkaline iodide sodium azide solution were added to each bottle. The bottles were stoppered, gently mixed, and allowed to settle. After floc settled, 2 mL of concentrated sulfuric acid were added. At this point, the mixture was stable and ready for titration. From each BOD bottle, 100 mL portions were taken and placed into separate 300 mL erlenmeyer flasks. Using a standard stabilized 0.025 N Sodium Thiosulfate solution, the samples were titrated to a pale yellow. Two mL of starch indicator solution were added which caused the solution to change from yellow to blue. Titration was then completed using the Sodium Thiosulfate solution read to 0.05 mL on the buret. Dissolved oxygen in parts-per-million (ppm) was equal to 2 x the mL amount of Sodium Thiosulfate used in the titration. The temperature of each sample was also recorded in order to calculate percent saturation. Readings were taken using a mercury thermometer, and saturation was determined using a nomogram (Rawson 1944).

Alkalinity was determined through titration of water samples with 0.02 N sulfuric acid. A 50 mL water sample was placed into 250 mL flasks and four drops of Phenophthalein indicator were added. The mixture was titrated to a faint pink color (pH 8.3) using the sulfuric acid. Next, four drops of Brom Cresol Green-Methyl Red indicator were added producing a blue color. Titration was continued with sulfuric acid until the solution changed from blue to faint pink (pH 4.8). Total alkalinity was then reported in ppm calcium carbonate by multiplying the total amount of sulfuric acid used by 20.

Chlorine, nitrate, and nitrite were analyzed using a Hach portable colorimeter and United States Environmental Agency approved tests. All tests used were as outlined in the Hach procedures manual for the portable colorimeter models DR/1A and DREL/1C. The methods used for each were total chlorine (DPD method), nitrogen nitrate (Nitraver 5), and nitrogen nitrite (Nitriver III).

Experimental fish were measured and weighed at the beginning and end of each experimental period. Fish were removed from individual aquaria, blotted to consistent wetness using a damp chamois, and weighed to the nearest 0.01 g using a Mettler top pan balance. They were then measured to the nearest mm in an extended, relaxed position, from the tip of the closed mouth to the tip of the lower caudal fin lobe. Measurements of length were made using pointed dividers. Following measurements, fish were returned to the assigned aquaria with a soft net to minimize excess handling and stress.

RESULTS

Water Quality Analysis

Complete water chemistry data for temperature, pH, dissolved oxygen, alkalinity, chlorine, nitrate, and nitrite were summarized according to date and location (Table 1).

The daily water temperature ranged between 58^oF and 69^oF, with an average of 63^oF. Fluctuations in the temperature were apparent (Figure 1). High, low, and mean values were observed over five day increments, measured at the east end of the tank near the standpipe. Water temperature of the system was influenced by factors beyond control during the experiment such as tap water fluctuations, environmental temperature variation, etc.

The pH in all sample locations throughout experimental periods remained relatively constant. The tank maintained a basic pH ranging between 7.6 and 8.5 standard units. Individual variation according to sample location was observed (Figure 2). Low and high pH values at specific sites were as follows: tap 7.6-7.8; dechlorination chamber exit 8.1-8.5; tank at standpipe 8.2-8.5; aquarium nine 8.2-8.5.

Dissolved oxygen also remained relatively constant. Averages for individual sites were 10.4 ppm at tap, 9.2 ppm at dechlorination chamber

Table 1. Water chemistry during fish growth experiments by date and site, for temperature, pH, dissolved oxygen, alkalinity, nitrate, and nitrite.

Site/Parameter	Date			
	12/18/91	1/3/92	1/27/92	2/13/92
Tap				
Temperature (oF)	56	58	57	58
pH (St. units)	7.6	7.6	7.7	7.8
Dissolved Oxygen (ppm)	10.0	10.4	10.4	10.8
Nitrate (ppm)	3.3	2.5	6.9	3.5
Nitrite (ppm)	0.01	0.01	0.01	0.01
Alkalinity (ppm)	282	278	230	246
Chlorine (ppm)	0.6	1.4	1.2	1.4
Dechlorination Exit				
Temperature (oF)	61	62	61	58
pH (St. units)	8.1	8.4	8.3	8.5
Dissolved Oxygen (ppm)	9.6	9.0	9.0	9.0
Nitrate (ppm)	3.5	3.0	5.7	3.8
Nitrite (ppm)	0.01	0.01	0.01	0.01
Alkalinity (ppm)	280	280	224	246
Chlorine (ppm)	0.8	1.0	0.7	0.9
Tank Standpipe				
Temperature (oF)	62	64	61	59
pH (St. units)	8.2	8.4	8.3	8.5
Dissolved Oxygen (ppm)	9.0	8.8	8.8	8.8
Nitrate (ppm)	3.6	2.9	3.9	4.9
Nitrite (ppm)	0.02	0.01	0.07	0.05
Alkalinity (ppm)	270	272	250	244
Chlorine (ppm)	0.1	0.1	0.0	0.0
Aquarium #9				
Temperature (oF)	64	62	62	59
pH (St. units)	8.2	8.5	8.2	8.5
Dissolved Oxygen (ppm)	9.4	8.2	8.4	8.2
Nitrate (ppm)	3.5	3.2	4.9	4.2
Nitrite (ppm)	0.02	0.01	0.03	0.05
Alkalinity (ppm)	296	274	248	244
Chlorine (ppm)	0.1	0.1	0.0	0.0

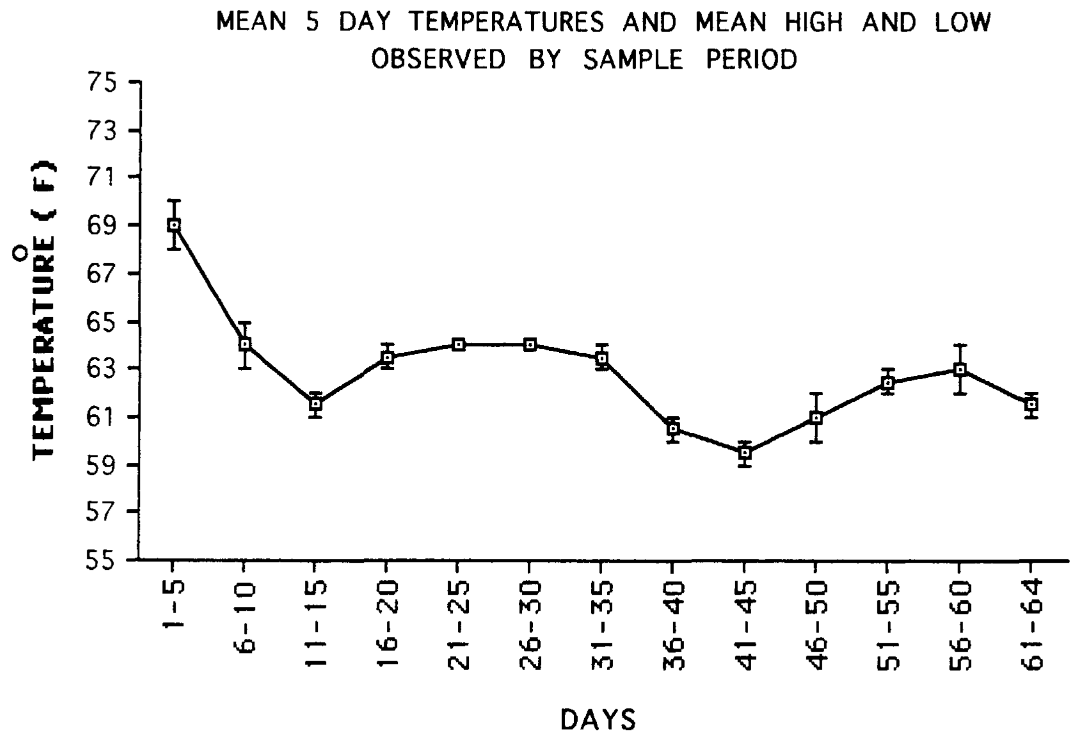
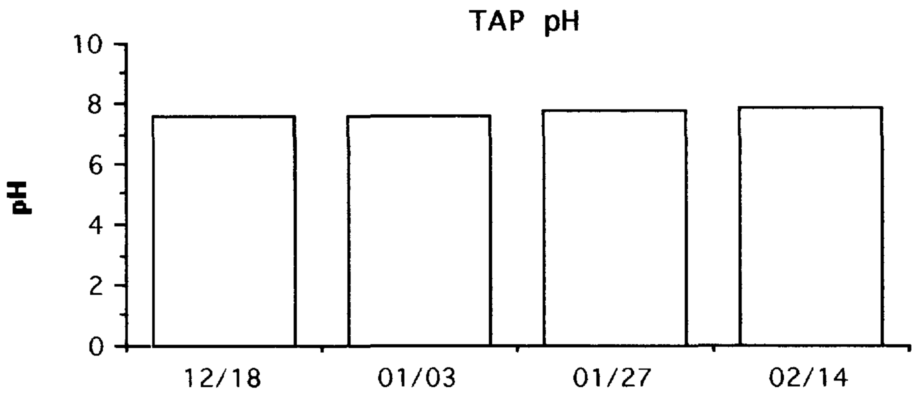
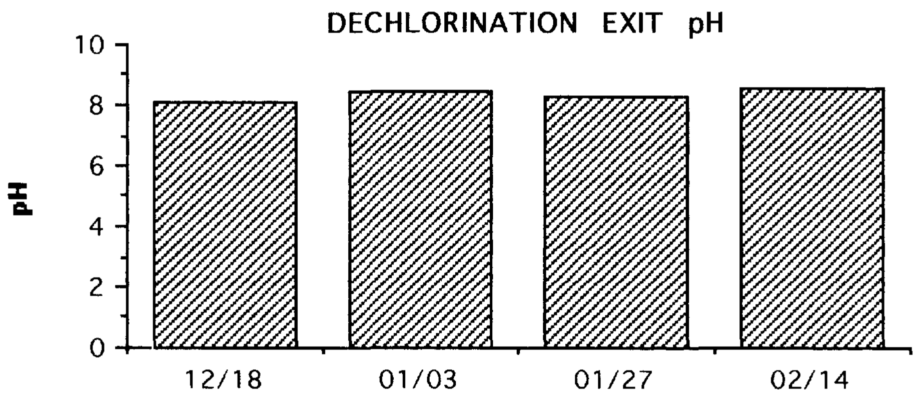
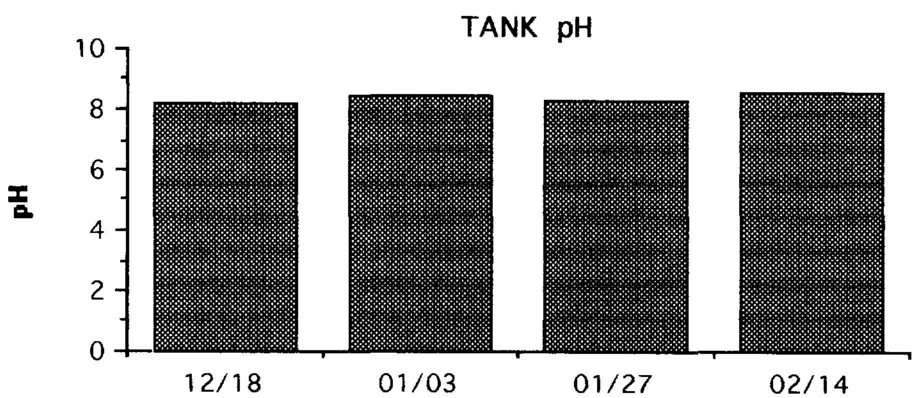
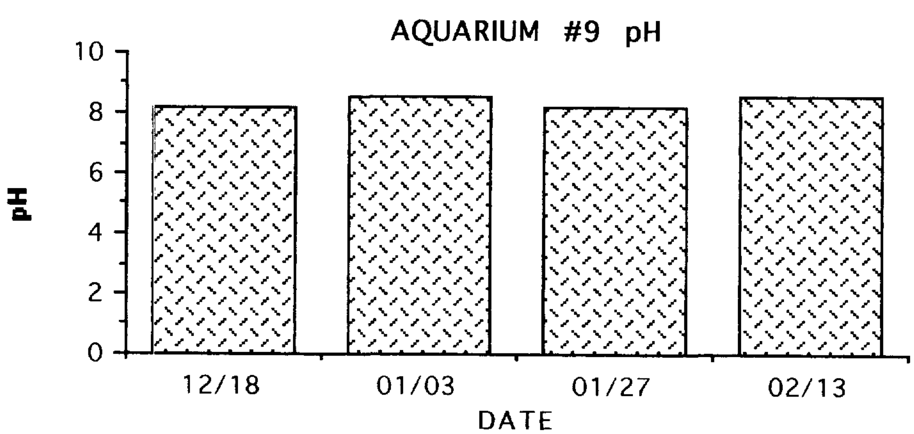


Figure 1. Mean water temperature and mean high and low temperature observed in the main raceway tank for five day intervals.


TAP pH
pH
10
8
6
4
2
0
12/18
01/03
01/27
02/14


DECHLORINATION EXIT pH
pH
10
8
6
4
2
0
12/18
01/03
01/27
02/14


TANK pH
pH
10
8
6
4
2
0
12/18
01/03
01/27
02/14


AQUARIUM #9 pH
pH
10
8
6
4
2
0
12/18
01/03
01/27
02/13
DATE

exit, 8.9 ppm in tank at standpipe, and 8.6 ppm in aquarium nine (Figure 3). Variation at these sites was slight (Figure 4). Dissolved oxygen during experiments ranged between 8.2 ppm and 10.8 ppm. Saturation was estimated as between 83% and 109% for the system. Percent saturation was usually between 90-100% (Figure 5).

Alkalinity exhibited only slight changes throughout the system. Averages for individual sites were 259 ppm at tap, 257 ppm at dechlorination exit, 259 ppm in tank at standpipe, and 265 ppm in aquarium nine (Figure 6). The alkalinity throughout the system ranged between 224 ppm and 296 ppm (Figure 7).

Chlorine levels remained below 0.1 ppm in the main raceway tank. Averages for the individual sites based on the four periods evaluated were 1.2 ppm at tap, 0.9 ppm at the dechlorination chamber exit, less than 0.1 ppm at the tank at standpipe, and less than 0.1 ppm in aquarium nine (Figure 8). Differences at individual sites were highest at the tap and dechlorination exit, but other sites were low and relatively uniform (Figure 9). Additionally, chlorine was monitored from the tap on a consistent basis every 5 - 10 days. Results of these measurements demonstrate only slight fluctuations in chlorine levels (Figure 10).

The range for nitrate concentrations was between 2.5 ppm and 6.9

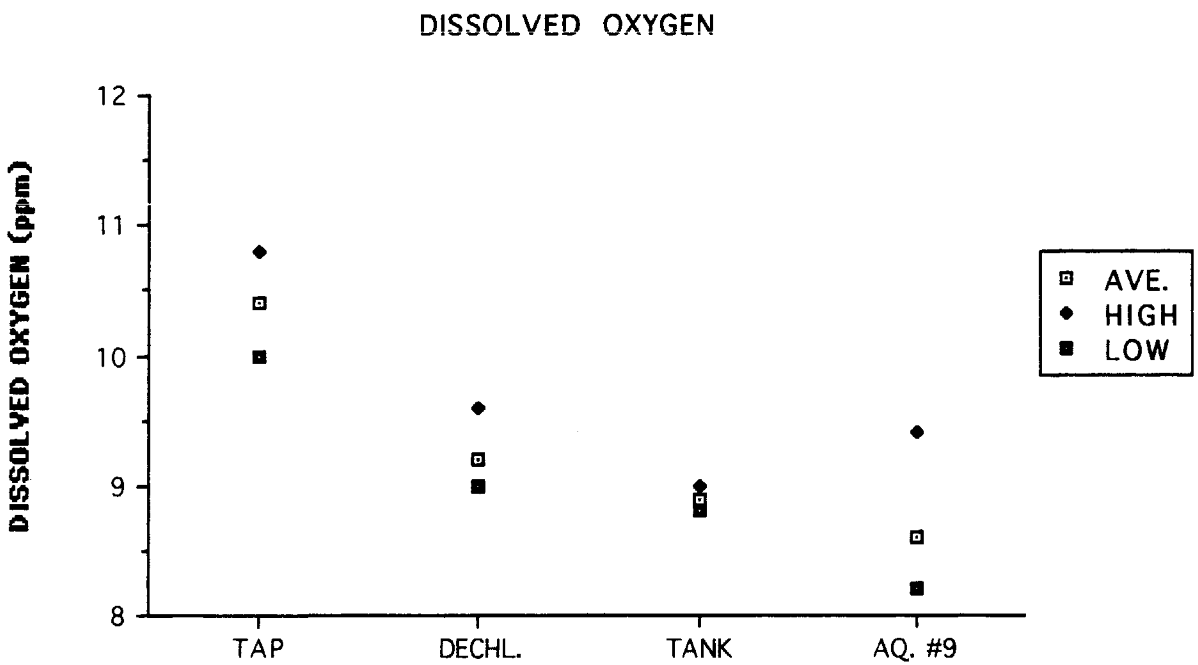
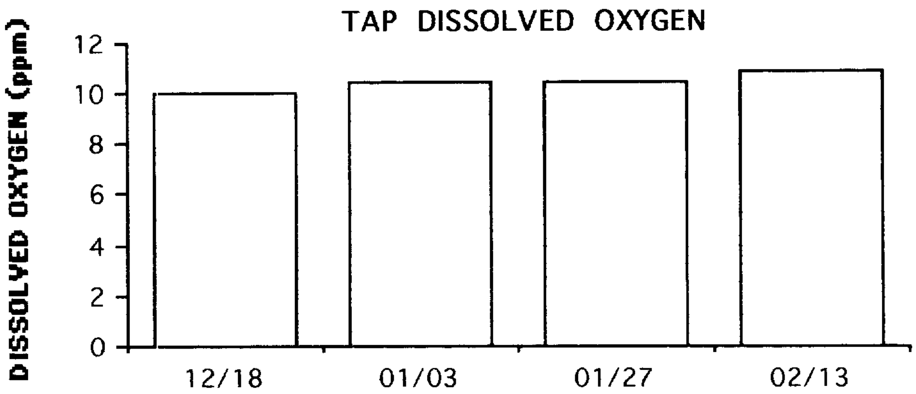
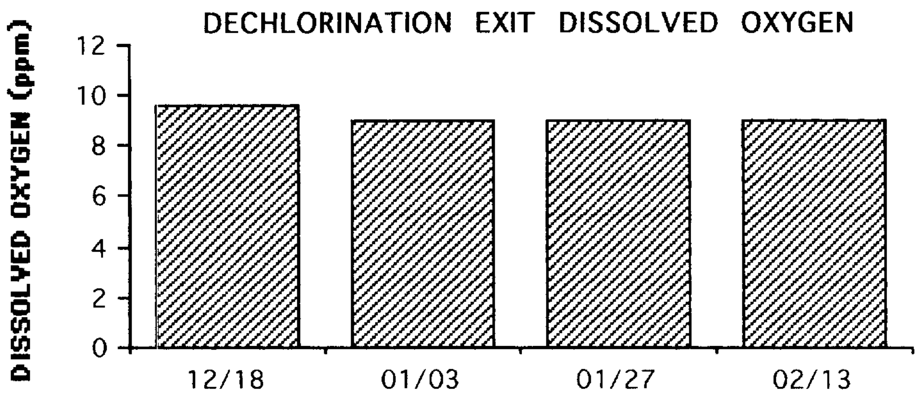


Figure 3. Dissolved oxygen high, low, and mean values at tap, dechlorination exit, tank, and aquarium #9.


TAP DISSOLVED OXYGEN
DISSOLVED OXYGEN (ppm)
12
10
8
6
4
2
0
12/18
01/03
01/27
02/13


DECHLORINATION EXIT DISSOLVED OXYGEN
DISSOLVED OXYGEN (ppm)
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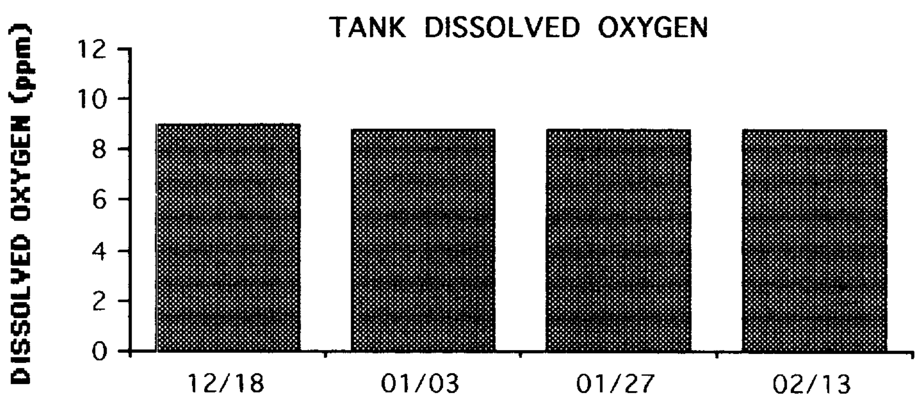
10
8
6
4
2
0
12/18
01/03
01/27
02/13


TANK DISSOLVED OXYGEN
DISSOLVED OXYGEN (ppm)
12
10
8
6
4
2
0
12/18
01/03
01/27
02/13

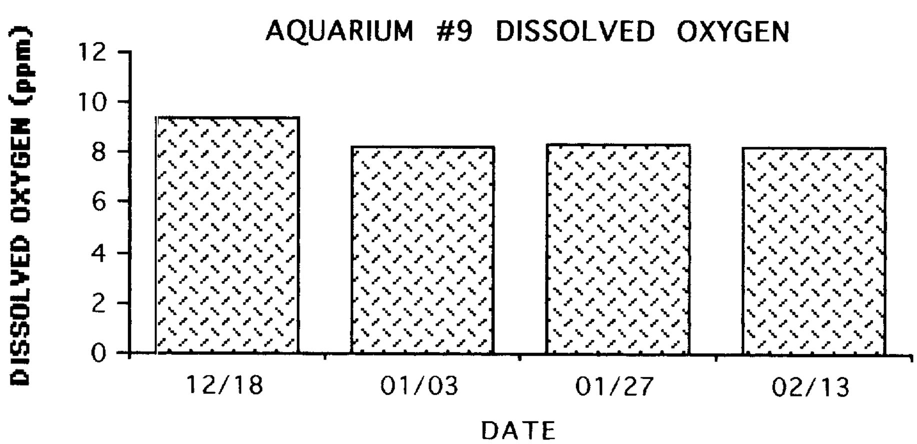
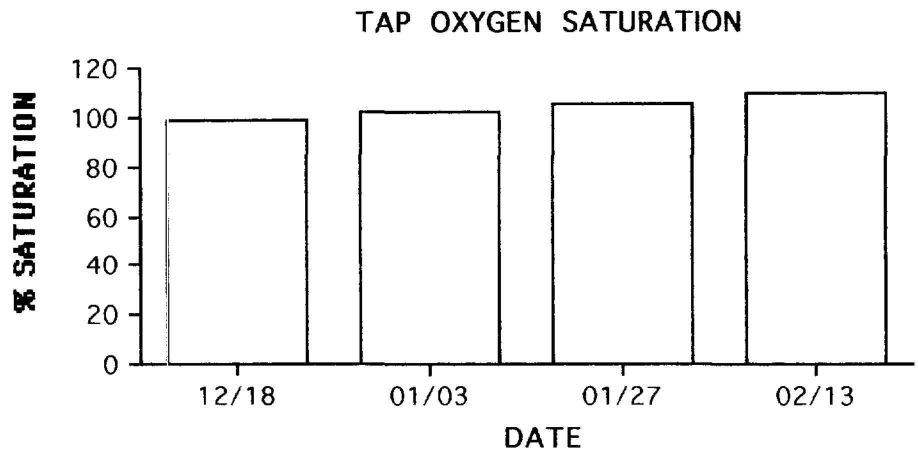

AQUARIUM #9 DISSOLVED OXYGEN
DISSOLVED OXYGEN (ppm)
12
10
8
6
4
2
0
12/18
01/03
01/27
02/13
DATE

Figure 5. Individual site locations for measurements of oxygen saturation: tap, dechlorination exit, tank, and aquarium #9.


TAP OXYGEN SATURATION
% SATURATION
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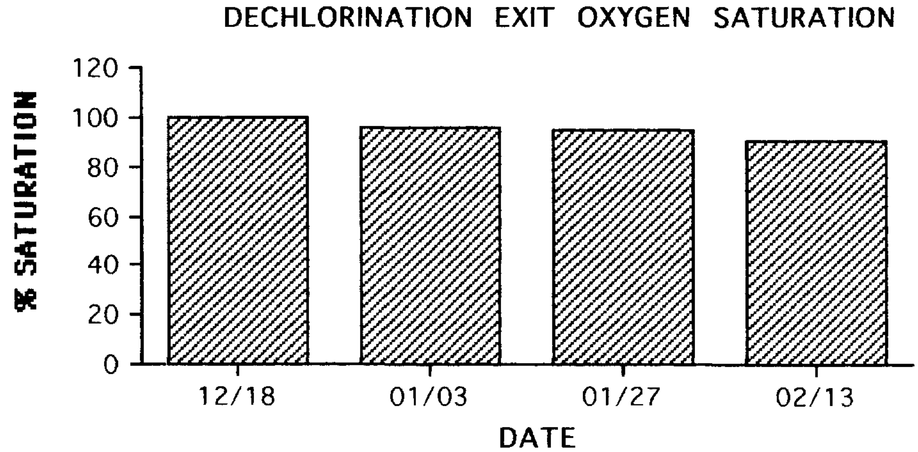
100
80
60
40
20
0
12/18
01/03
01/27
02/13
DATE


DECHLORINATION EXIT OXYGEN SATURATION
% SATURATION
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80
60
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20
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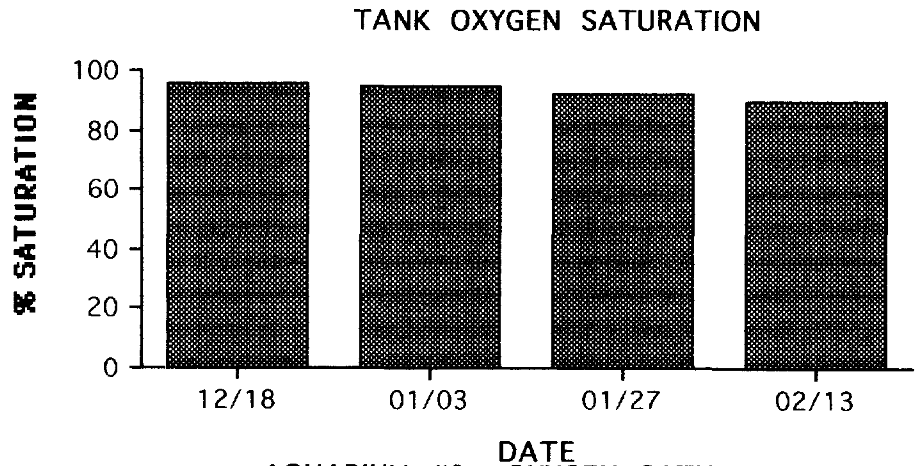
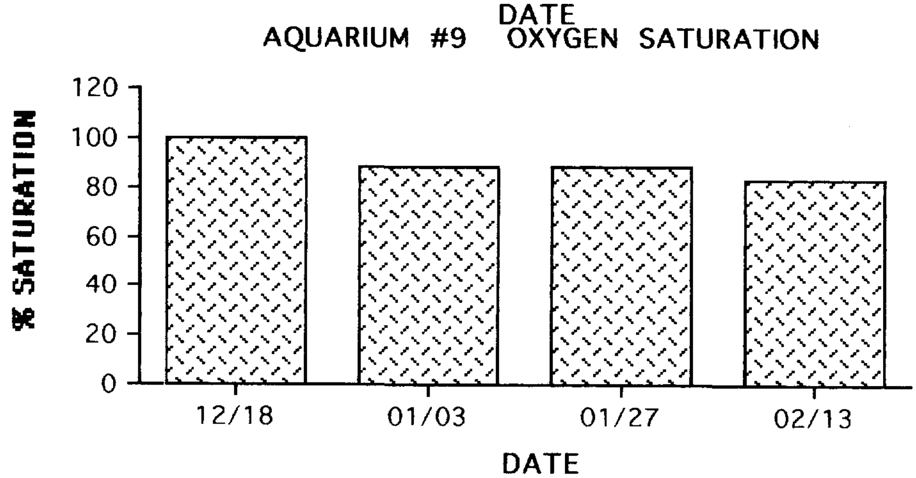
12/18
01/03
01/27
02/13
DATE


TANK OXYGEN SATURATION
% SATURATION
100
80
60
40
20
0
12/18
01/03
01/27
02/13
DATE


AQUARIUM #9 OXYGEN SATURATION
% SATURATION
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100
80
60
40
20
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12/18
01/03
01/27
02/13
DATE

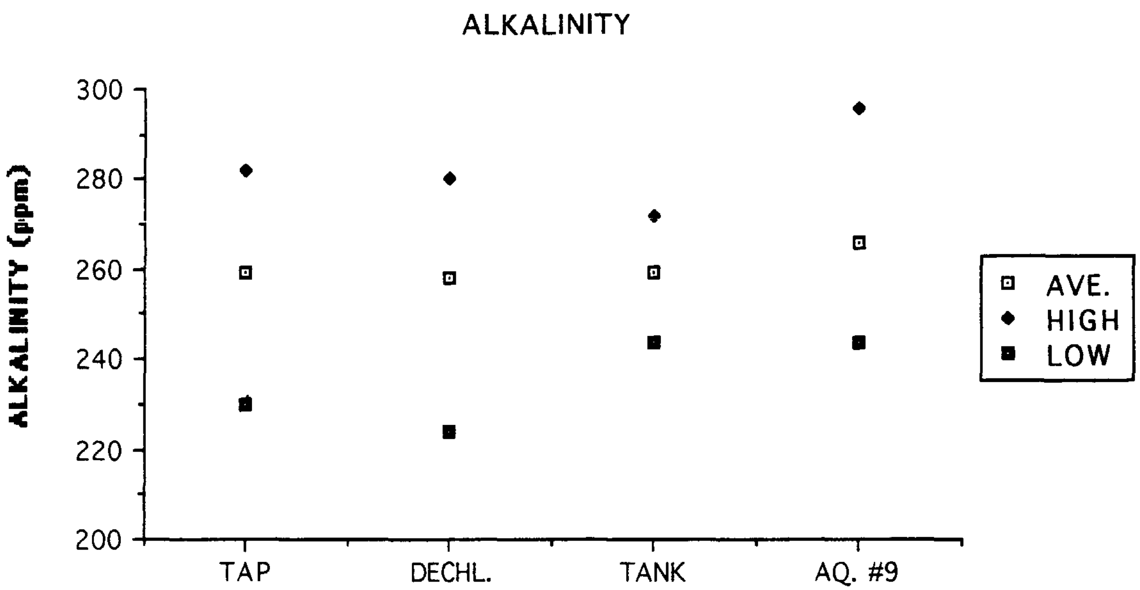
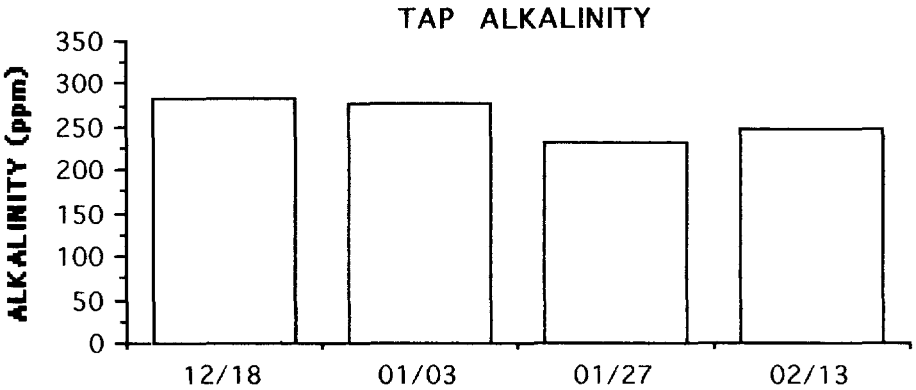
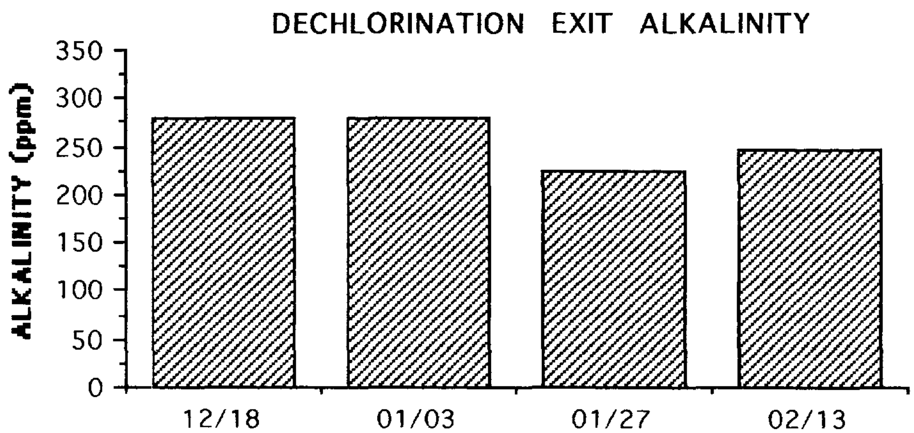
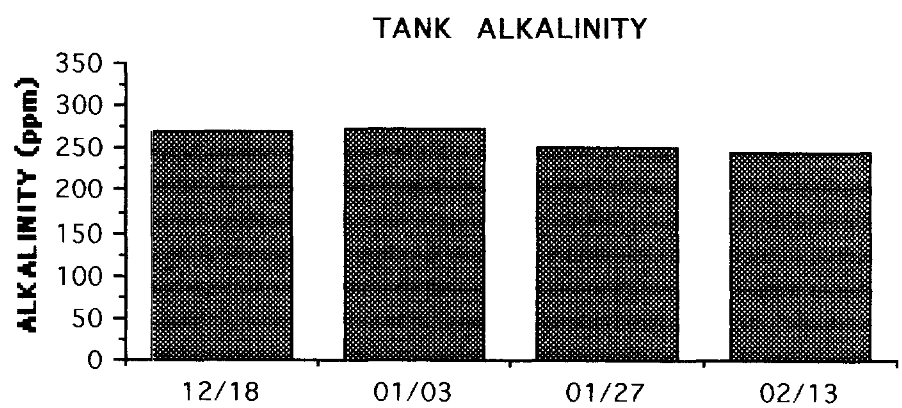


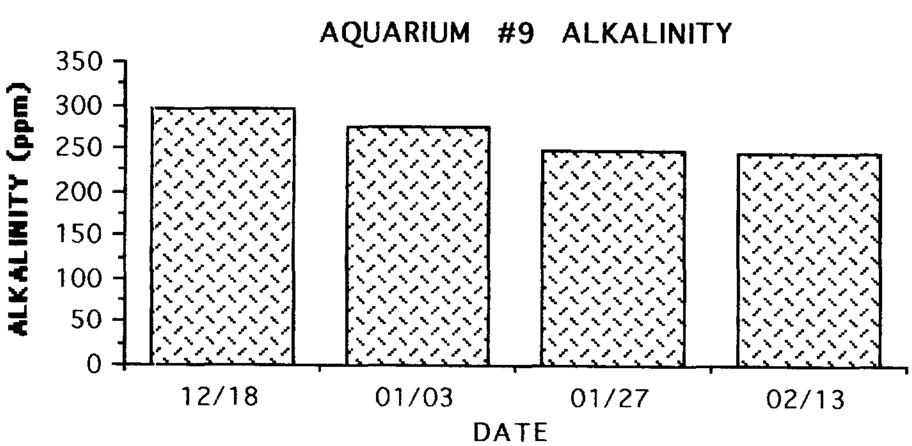
Figure 6. Alkalinity high, low, and mean values at tap, dechlorination exit, tank, and aquarium #9.

Figure 7. Individual site locations for measurements of alkalinity: tap, dechlorination exit, tank, and aquarium #9.


TAP ALKALINITY
350
300
250
200
150
100
50
0
ALKALINITY (ppm)
12/18
01/03
01/27
02/13


DECHLORINATION EXIT ALKALINITY
350
300
250
200
150
100
50
0
ALKALINITY (ppm)
12/18
01/03
01/27
02/13


TANK ALKALINITY
350
300
250
200
150
100
50
0
ALKALINITY (ppm)
12/18
01/03
01/27
02/13


AQUARIUM #9 ALKALINITY
350
300
250
200
150
100
50
0
ALKALINITY (ppm)
12/18
01/03
01/27
02/13
DATE

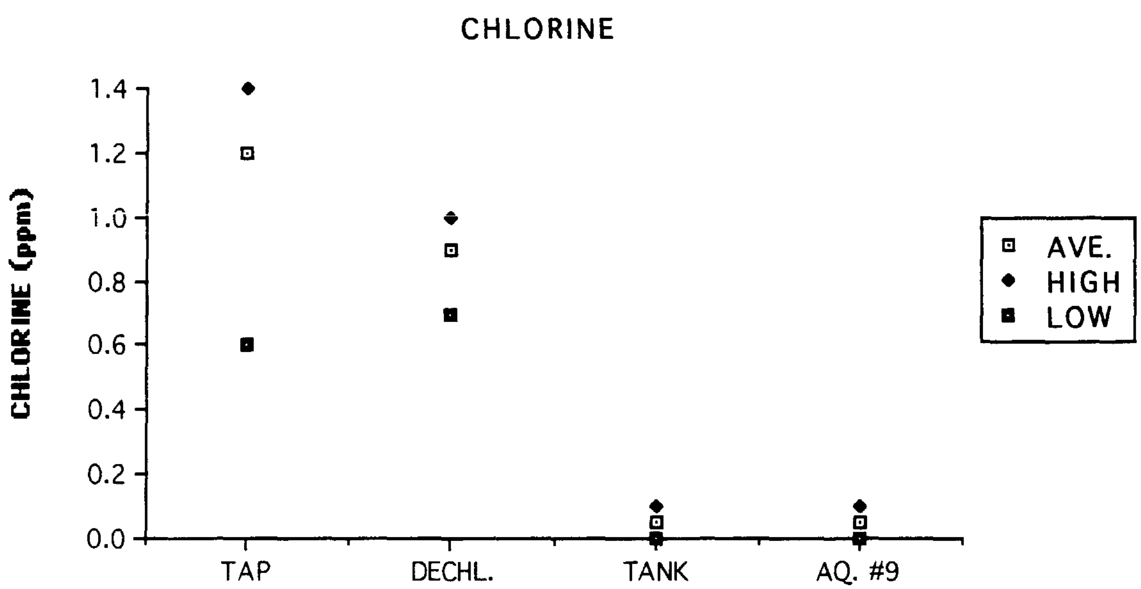
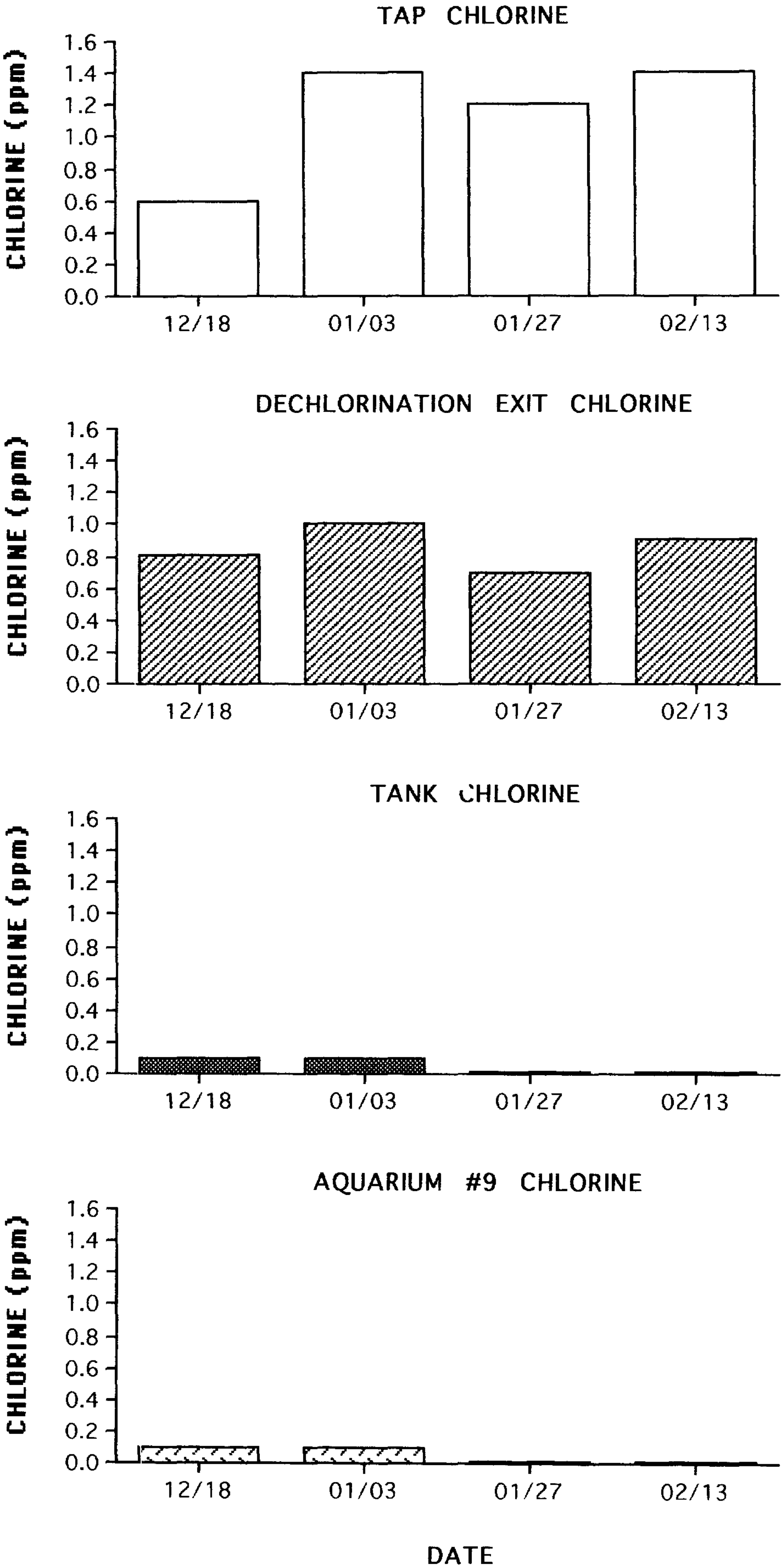


Figure 8. Chlorine high, low, and mean values at tap, dechlorination exit, tank, and aquarium #9.

Figure 9. Individual site locations for measurements of chlorine: tap, dechlorination exit, tank, and aquarium #9.



TAP CHLORINE
CHLORINE (ppm)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
12/18
01/03
01/27
02/13
DECHLORINATION EXIT CHLORINE
CHLORINE (ppm)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
12/18
01/03
01/27
02/13
TANK CHLORINE
CHLORINE (ppm)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
12/18
01/03
01/27
02/13
AQUARIUM #9 CHLORINE
CHLORINE (ppm)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
12/18
01/03
01/27
02/13
DATE

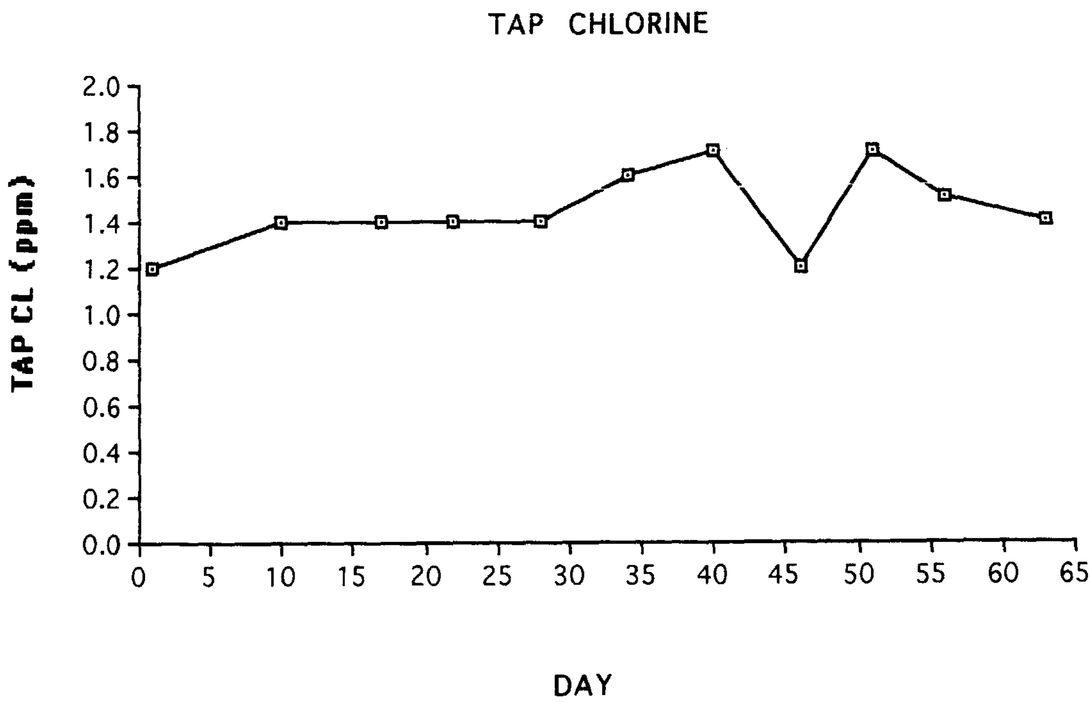


Figure 10. Mean chlorine levels, and mean high and low chlorine levels observed from the tap for five day intervals.

ppm. Averages for individual sites were 4.1 ppm at tap, 4.0 ppm at dechlorination chamber exit, 3.8 ppm in tank at standpipe, and 4.0 ppm in aquarium nine (Figure 11). Variation was greatest at tap and dechlorination chamber exit samples (Figure 12).

Nitrite was present only in trace amounts throughout the system ranging from 0.01ppm to 0.07 ppm. Averages for individual sites were 0.01 ppm at tap, 0.01 ppm at dechlorination chamber exit, 0.03 ppm in tank at standpipe, and 0.03 ppm in aquarium nine (Figure 13). There was a tendency for some buildup of nitrite in the aquaria and in the tank (Figure 14).

Feeding Results for Bluegill and Hybrid Sunfish

Results of feeding experiments for periods 1,2 and 3 were evaluated using the data base by period (Tables 2-4). Period 1 describes the dates of December 12, 1991 through January 2, 1992, inclusive; period 2, January 3 through January 22; and period 3, January 23 through February 14.

The total food consumed by hybrid sunfish in period 1 was 431.28 grams; in period 2, 544.44 grams; and in period 3, 772.08 grams. Average food consumed per day by period was 3.26 grams in period 1; 4.54 grams in period 2; and 5.85 grams in period 3. The total food consumed by bluegill